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(54) Device and method for separating components of a fluid sample

(57) A specimen collection and separation assembly is provided. The assembly includes a tube having closure. The closure includes a section that is pierceable by a needle. A separator is disposed in the tube below the closure. Portions of the separator adjacent the top define a resiliently deformable low density sealing plug dimensioned to sealingly engage the interior of the tube. A high density ring is integrally engaged with the seal and extends to the bottom of the separator. The relative densities and dimensions of the seal and the ring are selected to achieve an overall density between densities of the phases of liquid to be separated. The ring causes the seal to elongate in response to forces imposed by a centrifuge. The separator then will move to a position in the tube between the respective phases of the specimen being separated. Termination of the centrifugal load causes the seal to return to its initial shape and for isolating the separated phases of the speciment.

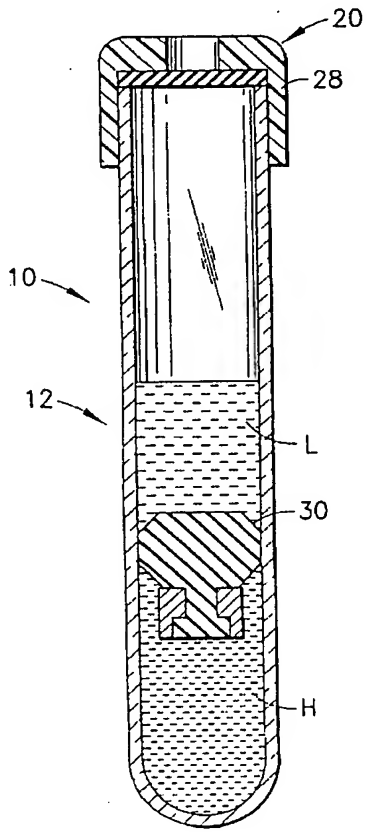

FIG.7

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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] This invention relates to a device and method for separating heavier and lighter fractions of a fluid sample. More particularly, this invention relates to a device and method for collecting and transporting fluid samples whereby the device and fluid sample are subjected to centrifugation in order to cause separation of the heavier fraction from the lighter fraction of the fluid sample.

2. Description of Related Art

[0002] Diagnostic tests may require separation of a patient's whole blood sample into components, such as serum or plasma, the lighter phase component, and red blood cells, the heavier phase component. Samples of whole blood are typically collected by venipuncture through a cannula or needle attached to a syringe or an evacuated collection tube. Separation of the blood into serum or plasma and red blood cells is then accomplished by rotation of the syringe or tube in a centrifuge. Such arrangements use a barrier for moving into an area adjacent the two phases of the sample being separated to maintain the components separated for subsequent examination of the individual components.

[0003] A variety of devices have been used in collection devices to divide the area between the heavier and lighter phases of a fluid sample.

[0004] The most widely used device includes thixotropic gel materials such as polyester gels in a tube. The present polyester gel serum separation tubes require special manufacturing equipment to prepare the gel and to fill the tubes. Moreover, the shelf-life of the product is limited in that overtime globules may be released from the gel mass. These globules have a specific gravity that is less than the separated serum and may float in the serum and may clog the measuring instruments, such as the instrument probes used during the clinical examination of the sample collected in the tube. Such clogging can lead to considerable downtime for the instrument to remove the clog.

[0005] No commercially available gel is completely chemically inert to all analytes. If certain drugs are present in the blood sample when it is taken, there can be an adverse chemical reaction with the gel interface.

[0006] Therefore, a need exists for a separator device that (i) is easily used to separate a blood sample; (ii) is independent of temperature during storage and shipping; (iii) is stable to radiation sterilization; (iv) employs the benefits of a thixotropic gel barrier yet avoids the many disadvantages of placing a gel in contact with the separated blood components; (v) minimizes cross contamination of the heavier and lighter phases of the sample during centrifugation; (vi) minimizes adhesion of the lower and higher density materials against the separator device; (vii) is able to move into position to form a barrier in less time than conventional methods and devices; (viii) is able to provide a clearer specimen with less cell contamination than conventional methods and devices; and (ix) can be used with standard sampling equipment.

SUMMARY OF THE INVENTION

[0007] The present invention is a method and assembly for separating a fluid sample into a higher specific gravity phase and a lower specific gravity phase. Desirably, the assembly of the present invention comprises a plurality of constituents. Preferably, the assembly comprises a container and a composite element.

[0008] Most preferably, the container is a tube and the composite element is a separator arranged to move in the tube under the action of centrifugal force in order to separate the portions of a fluid sample.

[0009] Most preferably, the tube comprises an open end, a closed end and a sidewall extending between the open end and closed end. The sidewall comprises an outer surface and an inner surface. The tube further comprises a closure disposed to fit in the open end of the tube with a resealable septum. Preferably, the separator element is releaseably positioned at the open end of the tube with the closure. Alternatively, the separator element may also be releasably positioned at the closed end of the tube.

[0010] Alternatively, both ends of the tube may be open, and both ends of the tube may be sealed by elastomeric closures. At least one of the closures of the tube may include a needle pierceable resealable septum.

[0011] Preferably, the separator is sealingly engaged with portions of the tube near the open top. The separator may be formed from a needle-pierceable resealable material that enables a needle cannula to be passed therethrough for depositing a specimen into the tube. The separator may be formed from a material that exhibits good sealing characteristics against the inner surface of the cylindrical sidewall of the tube, and may be diametrically dimensioned for sealing engagement against the sidewall of the tube. Thus the separator will isolate material on one side of the separator from material on the opposed side of the separator.

[0012] The separator may comprise a resiliently deformable material, such as thermoplastic elastomeric foam. The elastomeric portions of the separator are readily deformable and provide desirable sealing characteristics against the sidewall of the tube.

[0013] The separator further comprises a higher density portion integrally engaged with or embedded in the less dense elastomer. The more dense material preferably is disposed at a lower end of the separator. Thus, the higher density material functions to deform the separator downwardly into a smaller cross-sectional dimension during centrifugation. The more dense material al-

so functions to define an overall specific gravity or density for the separator that lies between the specific densities of the different phases of blood or other such liquid to be separated. The elastomeric portions of the separator may be at least partly hollowed to facilitate the deformation during centrifugation and to facilitate the needle piercing.

[0014] In use, a fluid enters the assembly by needle. The needle penetrates the closure and through the foam. or other elastomeric portions of the separator. The needle is withdrawn from the assembly and the septum of the closure and the separator reseals. The assembly then is placed in a centrifuge, and a centrifugal load is applied. The centrifugal load causes the more dense material embedded at the lower end of the separator to move downwardly in the tube, thereby elongating the separator and reducing the cross-sectional dimensions of the separator. As a result, the separator is able to move freely within the tube and moves into contact with the fluid to be separated. Simultaneously, the more dense phase of the fluid will move toward the lower end of the tube, while the less dense phase of the fluid will flow around the separator. The fluid eventually will be substantially divided into two separate phases with the separator positioned between the respective phases. The centrifuge then is stopped, and the elastomeric portion of the separator resiliently returns to its initial shape in sealing engagement with inner surfaces of the tube. Thus, the separator substantially separates the phases of blood and enables the respective phases to be separately analyzed.

DESCRIPTION OF THE DRAWINGS

[0015] The assembly of the present invention is advantageous over existing separation products that use gel. In particular, the assembly of the present invention will not interfere with analytes as compared to gels that may interfere with analytes. Another attribute of the present invention is that the assembly of the present invention will not interfere with therapeutic drug monitoring analytes.

[0016] Another notable advantage of the present invention is that fluid specimens are not subjected to low density gel residuals that are at times available in products that use gel.

[0017] A further attribute of the present invention is that there is no interference with instrument probes.

[0018] Another attribute of the present invention is that samples for blood banking tests are more acceptable than when a gel separator is used.

[0019] Another attribute of the present invention is that only the substantially cell-free serum fraction of a blood sample is exposed to the top surface of the separator, thus providing practitioners with a clean sample.

[0020] Additionally, the assembly of the present invention does not require any additional steps or treatment by a medical practitioner, whereby a blood or fluid sample is drawn in the standard fashion, using standard sampling equipment.

[0021] FIG. 1 is a front elevational view of the assembly of the present invention.

[0022] FIG. 2 is a perspective view of the separator in the assembly of FIG. 1.

[0023] FIG. 3 is a top plan view of the separator of FIG. 2

[0024] FIG. 4 is a cross sectional view of the separator of FIG. 3 taken along line 4-4 thereof.

[0025] FIG. 5 is a longitudinal cross-sectional view of the assembly of FIG. 1 taken along 5-5 thereof illustrating fluid delivery into the assembly by a needle.

[0026] FIG. 6 is a cross-sectional view of the assembly under centrifugation and the release of the separator from the tope of the tube.

[0027] FIG. 7 is a cross-sectional view of the assembly after centrifugation and the separation of the liquid sample into higher and lower specific gravities.

[0028] FIG. 8 is a top plan view of an alternate separation device.

[0029] FIG. 9 is a cross-sectional view taken along line 9-9 in FIG. 8.

[0030] FIG. 10 is a cross-sectional view similar to FIG. 9, but showing an alternate embodiment of the separation device.

DETAILED DESCRIPTION

[0031] The present invention may be embodied in other specific forms and is not limited to any specific embodiments described in detail, which are merely exemplary. Various other modifications will be apparent to and readily made by those skilled in the art without departing from the scope and spirit of the invention. The scope of the invention will be measured by the appended claims and their equivalents.

[0032] The present invention illustrated in FIGS. 1 and 5-7, wherein assembly **10** comprises a tube **12**, a closure **20** and a separator **30**.

[0033] Tube **12** comprises an open top **14**, a closed bottom **16** and a cylindrical sidewall **18** extending therebetween. Sidewall **18** of tube **12** has an inner surface **19** which defines a constant inside diameter **"a"**.

[0034] Closure **20** comprises a cylindrical top wall **22** and a downwardly depending cylindrical skirt **24**. Skirt **24** is dimensioned to telescope closely over portions of cylindrical sidewall **18** of tube **12** in proximity to open top **14**. Top wall **22** is generally annular and includes a central aperture **26**. Closure **20** further includes an elastomeric sealing layer **28** disposed adjacent portions of top wall **22** bounded by skirt **24** and extending continuously across aperture **26** in sidewall **22**. Sealing layer **28** is formed from a material that will sealingly engage open top **14** of tube **12** and that will reseal itself after piercing by a needle.

[0035] Separator **30**, as also shown in FIGS. 2-4, includes opposed top and bottom ends **32** and **34**. Por-

tions of separator **30** adjacent top end **32** define a toroidal seal **36**. Toroidal seal **36** is unitarily molded from a thermoplastic elastomer, such as a low density foam that is deformable, pierceable by a needle, resealable and sealingly engageable with adjacent surfaces. Toroidal seal **36** includes an intermediate portion **38** an outside diameter **"b"** which is slightly greater than inside diameter **"a"** of tubular sidewall **18** of tube **12**. As a result, intermediate portion **38** of seal **36** will sealingly engage inner circumferential surface of cylindrical sidewall **18** of tube **12**. Portions of seal **36** will sealingly engage inner circumferential surface of cylindrical sidewall **18** of tube **12**. Portions of seal **36** above and below intermediate portion **38** are tapered to smaller cross-sectional dimensions.

[0036] Separator **30** further includes a ballast mount **40** extending unitarily from seal **36** to bottom end **34** of separator **30**. Ballast mount **40** includes a small diameter cylindrical neck **42** adjacent seal **36** and a large diameter flange **44** adjacent bottom end **34**.

[0037] Separator **30** further includes a high density ballast ring **46** securely engaged around ballast mount **40**. Ring **46** is of stepped tubular configuration, and includes a top portion **48** with an inside diameter approximately equal to the diameter of neck **42** of mount **40**. High density ring **46** further includes a bottom portion **50** with an inside diameter approximately equal to the diameter of flange **44** of mount **40**. Ring **46** can be securely engaged on mount **40** by merely deforming flange **44** of mount **40** sufficiently for top portion **48** of ring **46** to pass upwardly and beyond flange **44**. When ring **46** abuts seal **36** of separator **30**, flange **44** of mount **40** will resiliently return to its initial position for securely engaging top portion **48** of ring **46** between flange **44** and seal **36**. Ring **46** preferably is formed from a metal that will be substantially non-reactive with the liquid to be collected and separated in assembly **10**. Additionally, ring **46** is dimensioned to provide an overall specific gravity for separator **30** that will be between the respective gravities of the separated phases of the liquid specimen that will be deposited in tube **12**.

[0038] Assembly **10** is assembled by inserting bottom end **34** of separator **30** into open top end **14** of tube **12**. Separator **30** is urged sufficiently into tube **12** for top end **32** of separator **30** to substantially align with open top end **14** of tube **12**. Closure **20** then is telescoped over open top end **14** of tube **12** such that the sealing layer **28** of closure **20** sealingly engages against open top **14** of tube **12**.

[0039] As shown in FIG. 5, a liquid sample **B** is delivered to the tube that penetrates closure **20** and through central portions of separator **30**. For purposes of illustration only, the liquid sample is blood.

[0040] As shown in FIG. 6, when subjected to a centrifugal load high density ring **46** moves toward bottom end **16**. The movement of ring **46** caused by the applied centrifugal load elongates seal **36** and causes intermediate portion **38** of seal **36** to move out of sealing engagement with inner surface **19** of cylindrical sidewall **18** of tube **12**. This separation of intermediate portion **38** from sidewall **18** of tube **12** enables separator **30** to move toward bottom end **16** of tube **12** in response to the centrifugal load. Simultaneously, blood deposited in tube **12** will separate into the low density liquid phase **"L"** and the high density formed phase **"H"**. The average specific gravity of separator **30** lies substantially between the specific gravities of separated phases **"L"** and **"H"** of the blood **"B"**. Hence, separator **30** will position itself substantially between the phases **"L"** and **"H"**as shown in FIG. 7.

[0041] The centrifuge is stopped after sufficient separation of phases **"L"** and **"H"** of the liquid specimen. Upon termination of the centrifugal load, separator **30** will return substantially to its initial shape with intermediate portion **38** sealingly engaging inner circumferential surface **19** of cylindrical sidewall **18** of tube **12**. Separated phases **"L"** and **"H"** then may be accessed and analyzed separately.

[0042] FIGS. 8 and 9 show an alternate separator **130**. Separator **130** includes a top end **132**, a bottom end **134** and a seal portion **136** extending therebetween. Seal portion **136** is unitarily molded from a thermoplastic elastomer, and preferably a low density form. An intermediate section of seal portion **136** is dimensioned to sealingly engage inner surface **19** of cylindrical sidewall **18** of tube **12**.

[0043] Separator **130** further includes a metallic ring **146** embedded in portions of separator **130** substantially adjacent bottom end **134** thereof. Ring **146** may, for example, be insert molded to remaining low density foam portions of separator **130**.

[0044] Separator **130** is assembled and performs substantially as the above-described first embodiment. More particularly, bottom end **134** of separator **130** is urged into open top end **14** of tube **12**. Closure **20** then is mounted to open top end **14** of tube **12** substantially as described above. A sample of blood or other liquid to be analyzed then is inserted into the tube assembly as described above, and the tube assembly then is centrifuged. The centrifugal load applied by the centrifuge causes metallic ring **146** to move downwardly in tube assembly **10**, thereby elongating separator **130**. This elongation enables separator **130** to move toward the bottom end of the tube in response to centrifugal loads, and further enables the low density phase of the blood to move around and past separator **130**. Assembly **10** will stabilize when the phases of blood or other liquid specimen have been fully separated, and when separator **130** is disposed between the phases. The centrifuge then can be stopped, thereby causing intermediate portions **136** of separator **130** to resiliently return to its initial shape. In this initial shape, separator **130** will sealingly engage inner surface **19** of cylindrical sidewall **18** of tube **12** for maintaining separation between the phases of blood.

[0045] A third embodiment of the separator is illustrat-

ed in FIG. 10, and is identified by the numeral **230**. Separator **230** is structurally and functionally very similar to separator **130** shown in FIGS. 8 and 9. In particular, separator **230** includes a top end **232** and an opposed bottom end **234**. A metal ring **246** is embedded in portions of separator **230** adjacent bottom end **234**. Separator **230** differs from the separator **130** in that the seal portion **236** is substantially hollow. The hollow configuration of the seal portion **236** facilitates deformation in response to centrifugal loads and further facilitates the piercing of separator **230** by a needle cannula for depositing a sample of blood or other liquid to be separated. The thickness of the walls of the hollow seal portion **236** can be selected to achieve a targeted overall specific gravity or density for separator **230** that is between the respective specific gravities of the phases of the liquid being separated.

[0046] While the invention has been described with respect to certain preferred embodiments, it is apparent that the first embodiment may be formed with a hollow seal portion as illustrated with respect to the third embodiment and other shapes for the seal portion and the high density ring may be employed.

Claims

1. A separator for use with a specimen collection tube for separating of a liquid specimen into phases having different densities, said separator having opposed top and bottom ends, portions of said separator adjacent said top end defining a low density deformable seal with an outside diameter selected for sealing engagement with said tube, portions of said separator adjacent said bottom end having a high density ring integrally engaged therewith, said high density ring having an outside diameter less than said outside diameter of said seal.

2. The separator of Claim 1, wherein said seal and the high density ring are formed from materials selected to define an overall density for said separator between the densities of said phases of liquid to be separated.

3. The separator of Claim 1, wherein said seal is formed from a thermoplastic elastomer.

4. The separator of Claim 3, wherein said thermoplastic elastomer is a low density foam.

5. The separator of Claim 1, wherein said high density ring is formed from a metallic material.

6. The separator of Claim 1, wherein said separator includes a ballast mount extending unitarily from said seal to said bottom end of said separator, said ballast mount including a cylindrical neck adjacent said seal and a flange extending outwardly from said seal neck adjacent said bottom end of said separator, said high density ring being of stepped tubular configuration and having a portion integrally engaged between said flange and said seal in surrounding relationship to said neck.

7. The separator of Claim 1, wherein said ring is embedded in portions of said seal adjacent said bottom end of said separator.

8. The separator of Claim 1, wherein said seal is hollow.

9. The specimen collection and separation assembly comprising:

   a specimen collection tube having a cylindrical sidewall with an open top and a closed bottom and a cylindrical wall extending therebetween, said cylindrical wall having an inner surface defining an inside diameter, a closure sealingly engaged with said open top of said tube, said closure having a top wall with a needle pierceable stopper extending across said open top of said tube;

   a separator engaged in said tube between said closure and said closed bottom of said tube, said separator having opposed top and bottom ends and comprising a seal adjacent said top end of said separator, said seal being formed from a resiliently deformable material and having a portion dimensioned for sealing engagement with said inner surface of said tube, a ring integrally engaged with said seal and extending to said bottom end of said separator, said ring having an outside diameter less than said inside diameter of said tube and being formed from a material more dense than said seal, such that said ring elongates and narrows said seal in said tube in response to a centrifugal load placed on said tube.

10. The assembly of Claim 9, wherein said separator includes a ballast mount unitary with said seal and extending toward said bottom end of said separator, said ring being securely engaged around said ballast mount.

ed in FIG. 10, and is identified by the numeral **230**. Separator **230** is structurally and functionally very similar to separator **130** shown in FIGS. 8 and 9. In particular, separator **230** includes a top end **232** and an opposed bottom end **234.** A metal ring **246** is embedded in portions of separator **230** adjacent bottom end **234**. Separator **230** differs from the separator **130** in that the seal portion **236** is substantially hollow. The hollow configuration of the seal portion **236** facilitates deformation in response to centrifugal loads and further facilitates the piercing of separator **230** by a needle cannula for depositing a sample of blood or other liquid to be separated. The thickness of the walls of the hollow seal portion **236** can be selected to achieve a targeted overall specific gravity or density for separator **230** that is between the respective specific gravities of the phases of the liquid being separated.

[0046] While the invention has been described with respect to certain preferred embodiments, it is apparent that the first embodiment may be formed with a hollow seal portion as illustrated with respect to the third embodiment and other shapes for the seal portion and the high density ring may be employed.

Claims

1. A separator for use with a specimen collection tube for separating of a liquid specimen into phases having different densities, said separator having opposed top and bottom ends, portions of said separator adjacent said top end defining a low density deformable seal with an outside diameter selected for sealing engagement with said tube, portions of said separator adjacent said bottom end having a high density ring integrally engaged therewith, said high density ring having an outside diameter less than said outside diameter of said seal.

2. The separator of Claim 1, wherein said seal and the high density ring are formed from materials selected to define an overall density for said separator between the densities of said phases of liquid to be separated.

3. The separator of Claim 1, wherein said seal is formed from a thermoplastic elastomer.

4. The separator of Claim 3, wherein said thermoplastic elastomer is a low density foam.

5. The separator of Claim 1, wherein said high density ring is formed from a metallic material.

6. The separator of Claim 1, wherein said separator includes a ballast mount extending unitarily from said seal to said bottom end of said separator, said ballast mount including a cylindrical neck adjacent said seal and a flange extending outwardly from said seal neck adjacent said bottom end of said separator, said high density ring being of stepped tubular configuration and having a portion integrally engaged between said flange and said seal in surrounding relationship to said neck.

7. The separator of Claim 1, wherein said ring is embedded in portions of said seal adjacent said bottom end of said separator.

8. The separator of Claim 1, wherein said seal is hollow.

9. The specimen collection and separation assembly comprising:

   a specimen collection tube having a cylindrical sidewall with an open top and a closed bottom and a cylindrical wall extending therebetween, said cylindrical wall having an inner surface defining an inside diameter, a closure sealingly engaged with said open top of said tube, said closure having a top wall with a needle pierceable stopper extending across said open top of said tube;

   a separator engaged in said tube between said closure and said closed bottom of said tube, said separator having opposed top and bottom ends and comprising a seal adjacent said top end of said separator, said seal being formed from a resiliently deformable material and having a portion dimensioned for sealing engagement with said inner surface of said tube, a ring integrally engaged with said seal and extending to said bottom end of said separator, said ring having an outside diameter less than said inside diameter of said tube and being formed from a material more dense than said seal, such that said ring elongates and narrows said seal in said tube in response to a centrifugal load placed on said tube.

10. The assembly of Claim 9, wherein said separator includes a ballast mount unitary with said seal and extending toward said bottom end of said separator, said ring being securely engaged around said ballast mount.

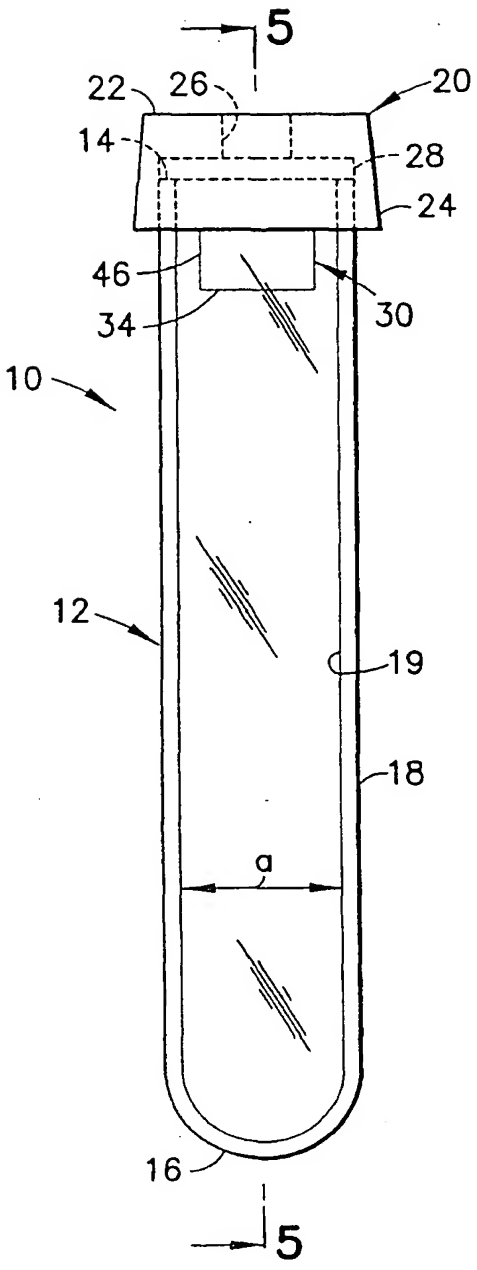
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FIG.1

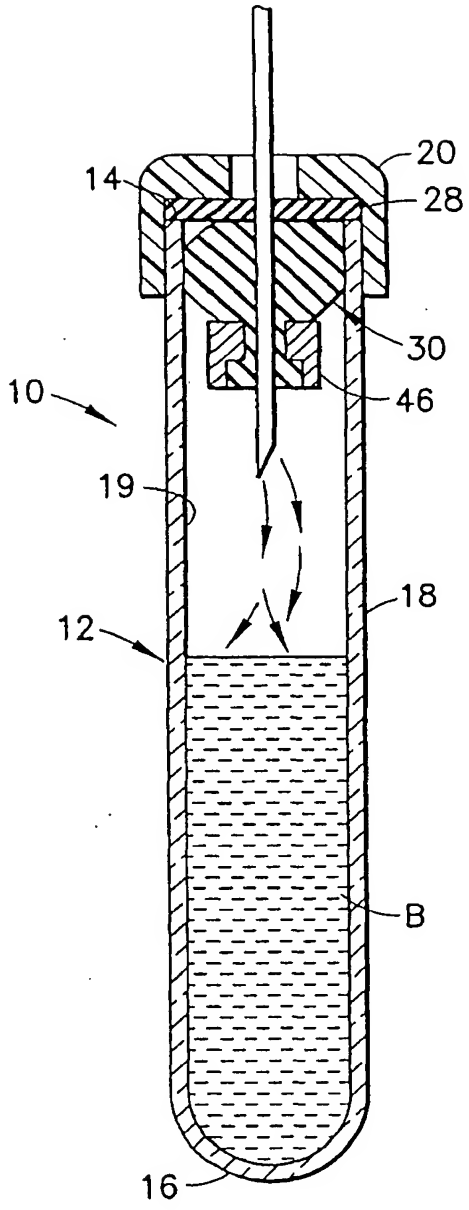
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FIG.5

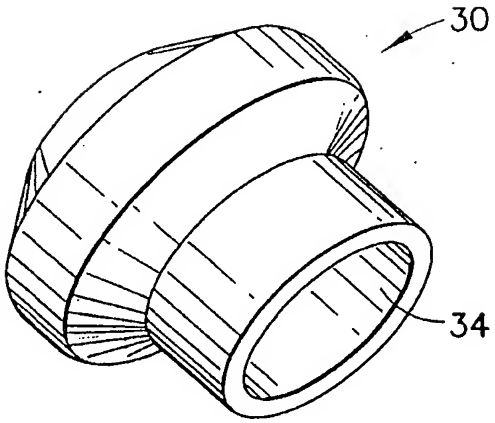

FIG.2

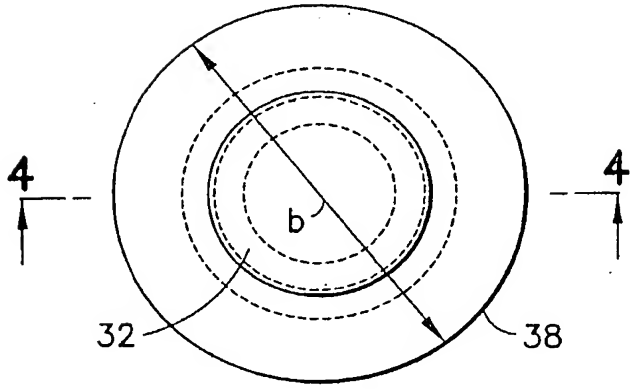

FIG.3

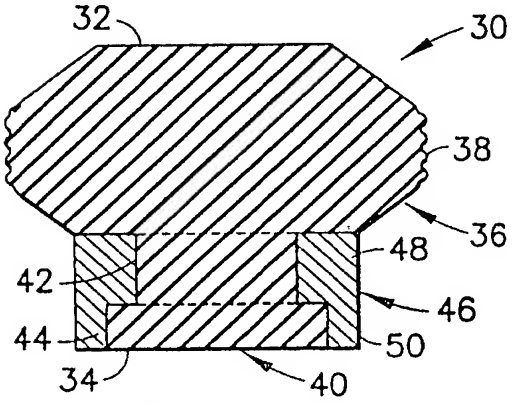

FIG.4

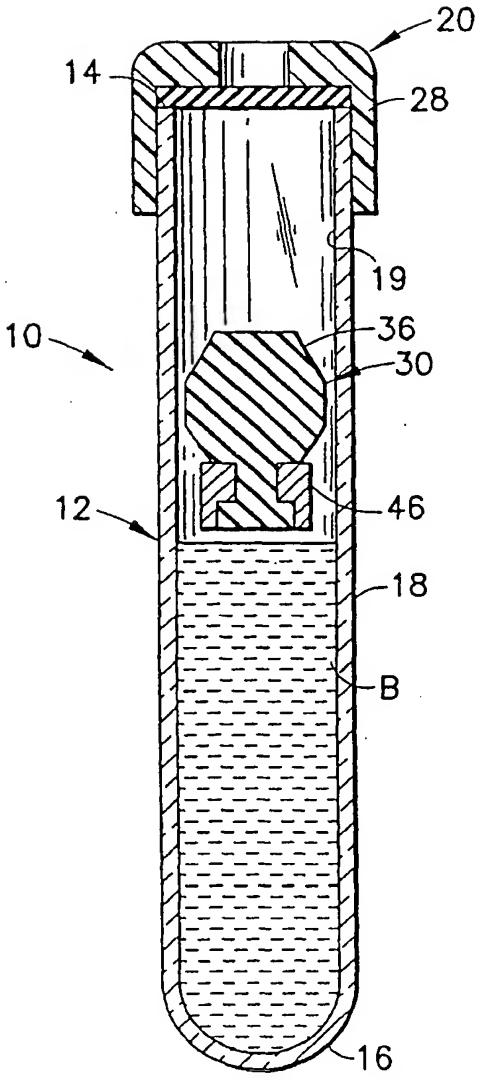

FIG.6

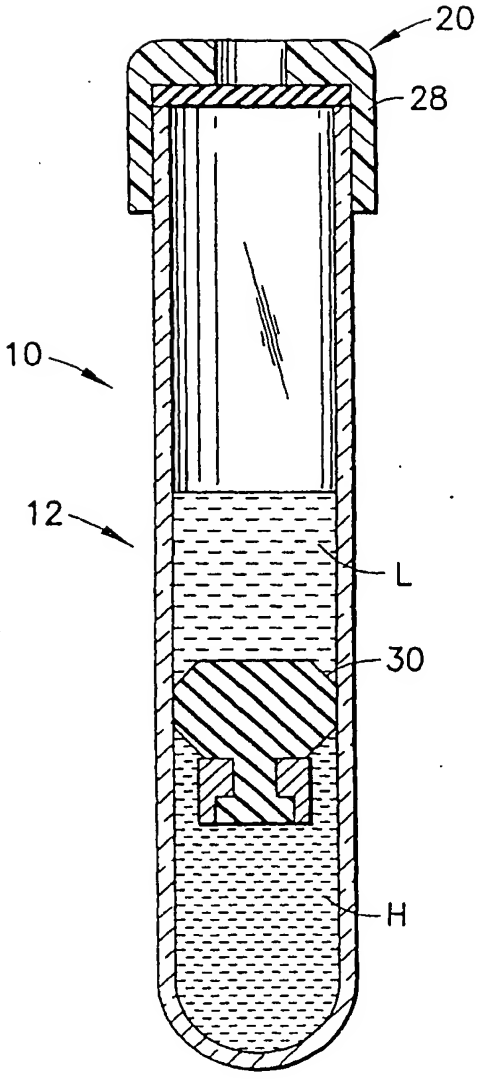

FIG.7

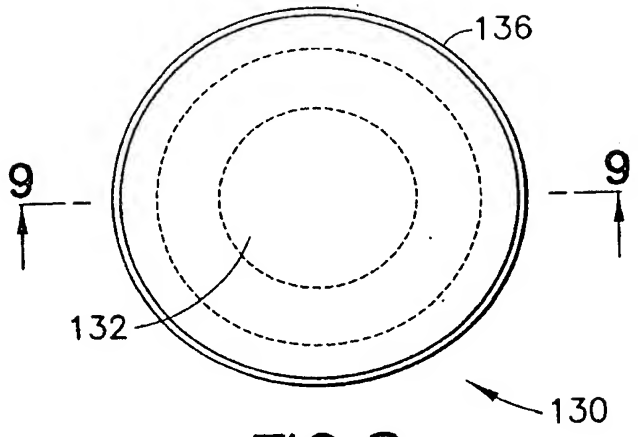

FIG.8

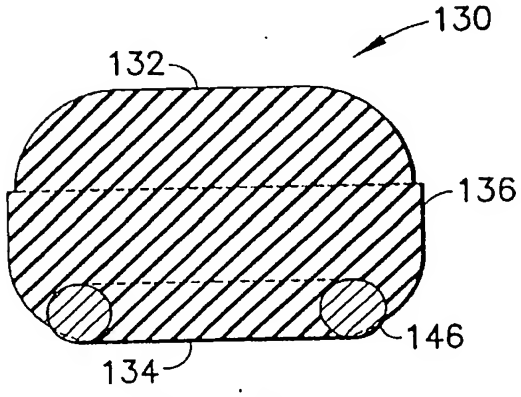

FIG.9

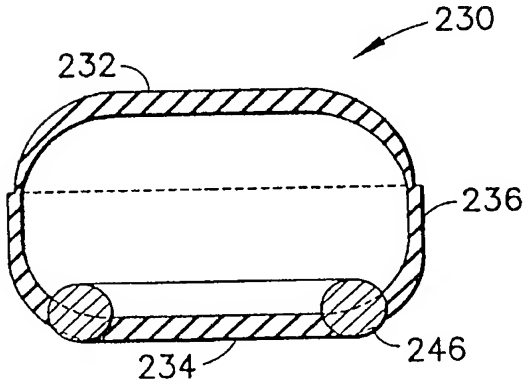

FIG.10